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RESEARCH ARTICLE

EFFECT OF BACKPACK ON GAIT KINETICS IN FRONTAL PLANE IN SCHOOL CHILDREN.

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Abstract

Frontal plane analysis during gait is an area which needs more investigations as the sagittal plane analysis is the always the subject of concern. Backpack carrying considered an everyday task during the school year. Carrying the backpack causes undesirable changes that affect different body systems. Purpose: The aim of our study was to determine the effect of backpack carrying on the hip abductors, the main pelvis stabilizer in the frontal plane, during gait. Thirty female normal children participated in this study. They were randomly selected from different schools at Giza government, Egypt. Their ages were ranged from 10-15 years old, their height ranged from 140-160 cm and their weight ranged from 40-50 Kg. Three dimensional motion analysis system with a force plate unit was used to measure the hip abductors moment during walking. The measurement was done with and without carrying a backpack weighted 15% of the subject's weight. The results: The results revealed that there was a significant increase in the hip abductors moment during walking while carrying a backpack when compared with walking without carrying backpack. The significant increase was detected in both right and left sides.

Conclusion and recommendations: - Carrying a backpack weighted 15% of the body weight causes increase in the hip abductor moment and so increase the demands on the body during walking. Further studies are needed to determine the effect of lighter ones.

Introduction:-

Standing or walking with backpacks shifts posterior and superior the combined center of mass of the system backpack and backpacker, inducing postural imbalance for static and dynamic conditions. When wearing a backpack there is an increase in the load carried by the musculoskeletal system, which may lead to adaptation in postures and forces acting on the human body. Many studies indicated that load carriage changed the kinematics and plantar pressures of walking. These biomechanical changes caused by load carriage might contribute to the high levels of back pain, muscle discomfort, joint problems, metatarsal stress, fractures, metatarsalgia, and foot blisters observed in people wearing backpacks (Castro et al., 2015).

Backpack is one of the most convenient ways to carry books and school supplies. Improper use of backpacks or very heavy one increases the risk of spinal injury (Cottalorda et al. 2004). Also backpack carrying appears to place increased demands on gait (Chow et al., 2005).

A poorly positioned backpack greatly affects posture and gait. The posture of the spine dramatically changes when the weight of the backpack increases. Gait responses to backpack loads are not entirely consistent and there is a particular lack of data regarding load-bearing gait (Cottalorda et al., 2003 and Daniel et al., 2005).

Several recent studies have drawn attention to the effect of the weight of the school backpack on children, particularly when its weight exceeds 20% of the child's body weight. Many children carry heavy backpacks which for some may weight 30% to 40% of their body weight. The maximum backpack weight should be 15% to 20% of the body weight (Cottalorda et al., 2004). Carrying a heavy backpack can be a source of chronic, low-level trauma, and can cause chronic shoulder, neck and back pain in children (Leffert, 2000).

Adverse effects of backpack:-

1- Postural changes.
2- Struggling when putting on or taking off the backpack.
3- Pain associated backpack with wearing.
4- Numbness in arms and legs.
5- Red marks on the shoulders.
6- Increased moments and power at the hip, knee and ankle showed increasing the demand on the musculoskeletal system (Daniel et al., 2005).

Drerup et al., (2004) found an increase in the plantar peak pressures distribution in the regions of the large toe, metatarsals, and heel which directly proportion with the carried weight. The increase in planter pressure in large toe, metatarsals, and heel amounted to 0.54, 0.76, and 0.38 N/cm per kg additional load, respectively.

There is effect of backpack on the vertical and anterior/posterior forces exerted on the upper and lower back. The lower back approximately bears 30% of the vertical force, the upper back and the remaining 70% is supported by shoulders. There is a direct relation between the peak forces on the upper and lower and backpack mass. It can be concluded that the backpack exerts constant force on the lower back, which contributes to the occurrence of low-back pain associated with load carriage. The 70% which born by shoulder and upper back can be reduced to approximately 40% of the vertical force generated by the backpack can be transferring the load to the lower back by using an external frame backpack with a hip belt (Lafiandra et al., 2004).

Adolescents' response to increasing posterior load, irrespective of backpack position, was to anterior placement of head, neck, shoulder, hip, thigh and knee in relation to the ankle joint. Shoulder displacement affects the movement of all points above it. This is reasonable because the need to adjust the body's center of gravity to accommodate a posterior load (Karen et al., 2002).

Hong and Cheung (2003) studied the effect of carrying backpack loads of 0, 10, 15, and 20% of the body weight during gait. Stride and temporal parameters, trunk lean angles and trunk motion range were analyzed. The results showed that both the backpack load and walking distance influence trunk inclination. If trunk inclination is taken as the criteria to determine permissible backpack loads for children, those loads should not exceed 15% body weight. In addition, walking distance should be considered when permissible loads are determined.

Children, especially young children, assume a compensatory forward head posture under backpack loads greater than 10%–15% of their body weight. Further research is needed to relate these findings to back pain, but it is suggested that, loads less than 10%–15% of body weight are required to maintain normal postural alignment (Erica, 2002).

Backpack carrying can affect the spinal inter-segmental mobility. When a 22.5 kg backpack situated at the thoracic level (T9) of the trunk, a significant decrease of the effective inter-segmental mobility between S1-L3-T12 was noticed. A decrease of inter-segmental mobility also appeared at the next level between L3-T12-T7. Also an increase of the inter-segmental mobility between T7-C7-external occipital tuberosity was noted (Vacheron, 1999).

Another potential danger of heavy backpacks is the increased risk of falls in students who wear them. In a study conducted by Nancy and Talbott (2002), sway length and sway area were calculated from the force plate measurements while performing a dynamic task. The type of backpack, the location of the backpack and the load in the backpack were varied. Results indicated that during static and dynamic tests, sway length and sway area were significantly greater with an increase in backpack weight. The type of backpack and the location of the backpack on the back were not significant. Other factors, including the history of pain associated with backpack wear and history of backpack related falls might be of greater importance to postural stability than the type or location of the backpack.

Students who carried packs weighting 25% of their body weight exhibited balance problems while performing normal activities such as climbing stairs or opening doors, which in turn increases their risk of falls. In contrast, students who carried packs weighing 15% of their body weight maintained their balance moderately well. Those carrying 5% of their body weight were most effective at maintaining balance, compared with their peers who carried more weight. These sensations of instability may be related to biomechanical changes associated with the type of backpack worn or the placement of the backpack on the spine backpack (Nicole et al., 2001).

Postural stability and body position while wearing a backpack weighing 20% of the body weight is significantly different from conditions in which no backpack or a backpack with 0 or 10% of the bodyweight is worn. Standing with a backpack that weighting 20% of the body weight results in an anterior movement of the shoulder and head, an increase in the movement of the center of pressure and an anterior, superior movement of the center of gravity (Nancy and Talbott, 2004).

The location of the backpack also significantly altered postural stability and posture. When the backpack was worn in the high position, postural stability, as indicated by decreased movement of the center of gravity within the base of support, was greater than the low position but the head was in a more anterior position. The type of backpack had no significant effect on postural stability or posture. In addition to the changes resulting from increase backpack weight and backpack location, it was found that, the gender, body mass index and age may also alter stability and posture when wearing backpacks ((Nancy and Talbott, 2004).

A study was conducted to determine if standing dynamic balance was affected by carrying a backpack. The results revealed that movement velocity significantly decreased during backpack loaded trials. No significant difference was found in reaction time or maximum excursion with backpack loading (Palumbo et al, 2001).

Walking speed and cadence decreased significantly with increasing backpack load, while double support time increased according to Wang et al., (2001). Kinematic changes were most marked at the proximal joints, with a decreased pelvic motion but a significant increase in the hip sagittal plane motion. Increased moments and power at the hip, knee and ankle showed increasing demand with backpack load. Parameters showed different responses to different loads, which may be due to increase the demands, so it is suggested that the critical load to be approximately 10% body weight (Daniel et al., 2005). Changes in gait and posture resulting from load carriage are largely a result of the body's attempt to increase stability (Orloff and rabb, 2003).

La Fiandra et al., (2004), found a significant effect of backpack carriage on the amplitudes of transverse pelvic and thoracic rotation and the relative phase of pelvic and thoracic rotation. They revealed that the shorter stride length and higher stride frequency observed when carrying a backpack is the result of decreased pelvic rotation. During unloaded walking, increases in pelvic rotation contribute to increases in stride length with increasing walking speed. The decreased pelvic rotation during load carriage requires an increased hip excursion to compensate for the decreased pelvic rotation. However, the increase in hip excursion is insufficient to fully compensate for the observed decrease in pelvis rotation, requiring an increase in stride frequency during load carriage to maintain a constant walking speed.

By Studying the effect of backpack loading on the gait pattern and compensatory strategy (which is important to the balance control) it was found that, there was an increase in the hip and knee joints flexion. Also there was an increase in the trunk flexion. The stride speed decreased apparently with loading on backs, but the stride length showed less changes. Besides, the responses to taking loads might be influenced by the strength of body (Wu et al., 2003).

An apparent multi-joints coordination motor mode was employed to compensate the influences of loading, however, their contributions are different; hip, knee joints and torso pitch made dominant contributions to the compensation while ankle joints made minor. The anterior pitch of upper torso could be employed to adjust the overall center of mass while loading on their backs. The larger the magnitude of loading on their backs, the larger the anterior pitch angle of torso. After the heel touched the ground, the flexion of hip and knee joints were effective for the shock absorption, which means that the stiffness of hip and knee joints can be used to absorb the shock and avoid the trauma of each joints (Wu et al., 2003).

The Kinematic and kinetic data of the hip, knee and ankle joints were studied during treadmill marches under three conditions by Quesada et al., (2000). The three conditions were 0%-body weight (BW) backpack load, 15%-BW load and 30%-BW load. The data was obtained, immediately before and after each treadmill march, for computing ankle, knee and hip joint rotations and moments. It was found that during load carriage trials prior to treadmill marches the peaks of hip extension, knee extension and ankle plantar flexion moments increased with increasing backpack load. The post-march peaks in hip extension and ankle plantar flexion moments were similar with all loads, while notable pre-march to post-march declines were observed for knee extension moment peaks, at 15%-BW and 30%-BW load.

Pre-march joint loading data suggested that the knee may produce substantial compensations during backpack loaded marching, perhaps to attenuate shock or reduce load elsewhere. Post-march kinetic data (particularly at 15%-BW and 30%-BW load), however, indicated that such knee mechanics were not sustained and suggested that excessive knee extensor fatigue may occur prior to march end, even though overall metabolic responses, at 15%BW and 30%-BW load, remained within generally recommended limits to prevent fatigue during prolonged work (Quesada et al. 2000).

Higher levels of upper and lower body torque were observed during backpack carriage than during unloaded walking. The differences in torque between loaded and unloaded walking suggest that a goal of loaded walking is to minimize upper body torque, which may reduce the likelihood of injury. Knowledge of the effects of load carriage on upper and lower body torque and related changes in coordination may provide insight into injury reduction mechanisms during load carriage (LaFiandra et al., 2004).

The purpose of the study:-

The purpose of the study was to determine the effect of backpack carrying on the hip abductor moment in the frontal plane. Hip abductors were selected as they considered the main stabilizer of the body during single limb stance and have an important role in maintaining the balance of the body during gait by decreasing the deviation of the body center of gravity.

Subjects and methods:-

1-Subjects:-

The subjects participating in this study was 30 female normal healthy students, were selected from different schools at Giza government.

Subjects Criteria:-

1. Age: ranged from 10-15 years old.
2. Height: ranged from 140-160 cm.
3. Weight: ranged from 40-50 Kg.
4. Free from any musculoskeletal abnormalities that affect walking.
5. They used to carry backpack as a method for carrying the school materials.

Methods:-

A- Instrumentations:-

I-The backpack:-

Two straps backpack with the following criteria was used:-

1. Two wide shoulder straps with adjustable length.
2. Padded back to reduce pressure on the back, shoulders, and under arm regions.
3. Hip belt to transfer some of the backpack weight from the back and shoulders to the hips and torso.
4. The backpack was prepared by putting some of the school materials within it to weight 15% of the subject's weight.

II-Three dimensional motion analysis system with a force plate unit:-

The system consists of:-

1. Motion capture unit

2. Wand kit:
3. Reflective markers:
4. Personal computer for data processing and analysis

B- Procedures:-

I-Subjects preparation:-

Before starting the procedures all subjects were instructed fully about the testing procedures and informed consents were obtained from parents (appendix I). The weight and height of the subject were measured and recorded. The bag was set to weigh 15% of the subject's weight.

II-System calibration:-

Before the 3D capture was performed, camera system and the force platform were calibrated using a software calibration technique. This enables the cameras to pick up the markers position throughout the whole measurement volume.

III-Markers placement:-

Reflective markers were placed at anatomical landmarks as indicated by the manufacturer catalogue.

VI-Capturing:-

1. All subjects were instructed to walk freely with their normal walking speed on the walkway.
2. Capturing the kinetic data was performed to the subjects while walking without carrying any load and while carrying a backpack weighted 15% of the subject weight.

VI-Data analysis:-

The captured data were analyzed using software to calculate the hip peak abductor moment at each trial.

Study and Statistical design:-

The research design of this study was case control design and the statistical analysis was done using MANOVA.

Results:-

The independent variable in this study was the backpack carrying and the dependent variable was the hip abductor moment. The dependent variable had a two levels (right and left sides) so MANOVA test was used.

The results of the study showed that the mean value of the right hip abductor moment (M_{Rt}.) and that of the left hip abductor moment (M_{Lt}.) without carrying the backpack were0.4033/Kg (±0.0486) and 0.4013N.m/Kg (±0.0511) respectively. During carrying the backpack the values became0.477N.m/Kg (±0.054).and 0.473N.m/Kg (±0.0573) for right and lift sides respectively. There was a significant increase in the values of hip abductors moments during walking while carrying the backpack.

Table (1):MANOVA and LSD tests for hip abductor moment with and without carrying backpack.

X ± SD	Without carrying		With carrying	
	M_{Rt}	M_{Lt}.	M_{Rt}	M_{Lt}.
	0.4033±0.0486	0.4013±0.0511	0.477±0.054	0.473±0.0573
MANOVA				
F	76.66			
P	<0.05			
LSD				
With carrying		vs	Without carrying	p
M_{Rt}		vs	M_{Rt}	<0.05
M_{Lt}		vs	M_{Lt}.	<0.05

Discussion:-

The results of the current study showed a significant increase in the hip abductor moment during gait as a result of backpack carrying. This may be attributed to the increased demands on the muscular activity due to the weight of the backpack.

The hip abductors muscles play an important role in support of the body weight especially during single limb stance. The body weight acting through the center of gravity tends to drop the pelvis in the frontal plane at the hip joint by creating adduction moment. This action of the body weight is counterbalanced by the action of the hip abductors which create abduction moment (Jacobs et al., 2007).

So the increase in the body weight will increase the demands on the hip abductors which should increase their moment to withstand the increase in the body weight. In the current study carrying the backpack was the source of body weight increase which required the increased activity of hip abductor.

Our results come in agreement with Chow et al., (2005) who conducted a study on gait patterns of 22 normal adolescent girls. Parameters were recorded using backpack loads of 0, 7.5, 10.0, 12.5 and 15.0% body weight. Temporal-distance, ground reaction force and joint kinematic, moment and power parameters were analyzed.

Walking speed and cadence decreased significantly with increasing backpack load, while double support time increased. Kinematic changes were most marked at the proximal joints, with a decreased pelvic motion but a significant increase in the hip sagittal plane motion. Increased moments and power at the hip, knee and ankle showed increasing demand with backpack load.

The results of Hong &Brueggemann, (2000), supported our findings. They examined the gait pattern, heart rate and blood pressure in children carrying school bags of 0 (as control), 10, 15 and 20% of their own body weight whilst walking on a treadmill. When compared to the 0% load condition, the 20% load condition induced a significant increase in trunk forward lean, double support and stance duration, and decreased trunk angular motion and swing duration and a prolonged blood pressure recovery time. The 15% load condition induced a significant increase in trunk forward lean and prolonged blood pressure recovery time. No significant difference was found in the measured parameters between the 10 and 0% load conditions

Also, Mackenzie et al., (2003), findings were parallel to our findings. They stated that, back pain and deformity are common in adolescents. There has been extensive discussion in the lay literature as to the potential for back pain and spinal deformity with backpack use. The scientific literature on this subject is sparse but is increasing. Epidemiologic studies have identified risk factors associated with back pain in adolescents and daily use of a heavy backpack may be important. A book bag weighing more than 15% to 20% of a child's weight is associated with back pain, and improper use of the backpack can result in changes of posture and gait. There is no evidence that structural spinal deformity can result from backpack use. Children who experience back pain are at increased risk of having back pain as adults

Conclusion:-

According to the results of this study, it can be concluded that carrying a backpack with a weight of 15% of the subject’s body weight will significantly increase the hip abductors moment. This increase in the hip abductors moment indicates increased demands on the subjects carrying the backpack, which can adversely, affects the subjects’ health.

Recommendations:-

1. The weight of the backpack should be less than 15% of the subject weight.
2. Repeat the same study using different weights (lessthan15% of the body weight) to determine the safest one.
3. Conducting further studies to assess the other gait parameters.

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